Bently's Corner

Monitoring rolling element bearings

By Donald E. Bently

Rolling element bearings have long presented a difficult set of monitoring problems for the machinery engineer. Unlike fluid film bearings, analysis of imbalance and other rotor dynamics problems has been difficult. Available bearing failure prediction methods have yielded only mediocre succes.

Bently Nevada is developing a new concept that can provide direct measurement of bearing activity and may allow for balancing and analysis of machines with rolling element bearings.

Many attempts have been made to predict the failure of rolling element bearings. Until some recent work by the U.S. Navy, the most popular methods have centered on attempts to measure the spike energy generated by rolling element flaws using high frequency accelerometers.

The most commonly used method has been to observe the spike energy in the self-resonant region of an accelerometer. This resonance is often in the region of 30,000 to 50,000 Hz as shown in Figure 1. The success of this technique has been limited by operator difficulty in interpreting the observed data.

New Prediction Method

Bently Nevada's new process employs ideas pioneered by Gerald J. Phillips at the David Taylor Research and Development Center of the U.S. Navy. His method uses a fiber optic probe to observe the deflection of the outer race of the rolling element bearing with respect to the bearing housing.

Bently Nevada's new process is based on a special high sensitivity eddy current proximity probe, rather than a fiber optics probe, which measures the deflection of the bearing outer race as the rolling element passes beneath it. Spalls in the rolling elements and races are easily detected. In addition, information that provides the magnitude and phase angle of imbalance can be obtained.

The eddy current probe offers significant cost and performance advantages over fiber optic transducers. Figure 2 shows a typical installation of the transducer. Figures 3 and 4 are photos of an actual installation on a 40 horsepower 1800 rpm motor which drives a small plant air compressor. In this installation, probes were put at a 90° orientation at both end bearings to study the rotor and bearing behavior.

A very slight relief of the housing is provided to allow the probe to observe the deflection of the outer race as each rolling element passes over the observed point. The relief can be small enough so that the normal bearing life is not affected. Typical deflections are in the order of 2 to 100 microinches. Bearing manufacturers suggest that the relief be not more than half the angle subtended between rolling elements. Thus, a nine element bearing could possibly have a 20° relief.

Malfunction Classifications

Malfunctions of machinery equipped with rolling element bearings can be classified into two basic categories: 1) Those common to all rotating machinery (generally rotor-related), such as imbalance, misalignment, rubs, resonance excitation, etc.; and 2) direct failure of the rolling element bearing due to component defects, improper lubrication, misinstallation, etc.

Fortunately, for the purpose of detecting and separating these two malfunction classes, there is a unique vibration frequency range for each malfunction category: 1) Rotor related malfunctions occur at relatively low frequencies and 2) failed or failing bearings occur at higher frequencies. Of course, a malfunction of the first category could

precipitate a malfunction of the second, but an early warning monitor system would detect this.

Steady state load, such as from misalignment and gravity, etc., appears at roller passage frequency (RPx) and twice rotative speed. Imbalance and rotor bows show up as rotative speed (1x) and roller passage frequency (RPx).

Rotor instabilities appear at the instability rate (usually at balance resonance below rotative speed) plus RPx. Rubs may show at a wide variety of frequencies above and below rotative speed, depending on the type and severity of the rotor rub.

Faulty bearing installation flaws generally appear as various combinations of 1x, 2x, and RPx. If the transducer is in the load zone, increases in load result in an increased outer race deflection.

Detecting Rolling Element Malfunctions

Malfunctions of the rolling elements themselves have long been recognized by spikes of transmitted forces which occur when the flaws appear on any or all of the elements (inner race, rollers, or outer race). It is also well known that these spikes increase in frequency of occurrence and amplitude as deterioration progresses, and that the failure feeds on itself. One flaw creates more flaws, which create even more flaws, so that an exponential degradation is common for such bearings.

Bently Nevada's Rolling Element Bearing Activity Monitor (REBAM™) improves the detection of both classes of machine malfunctions. The accelerometer has never been highly sensitive to the low frequency rotor data. The high sensitivity eddy current proximity probe, used with the REBAM, directly observes the action of the bearing and is highly sensitive to low frequency rotor data.

The primary frequency content range of the flaw-induced spike is on the order of 5 to 15 times the roller passage rate. The roller passage rate of most antifriction bearings is on the order of 2 to 4 times shaft rpm. Thus, the spike frequency appears on the order of 10

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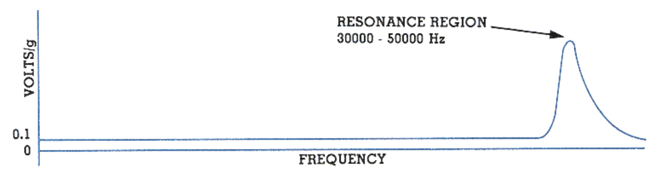
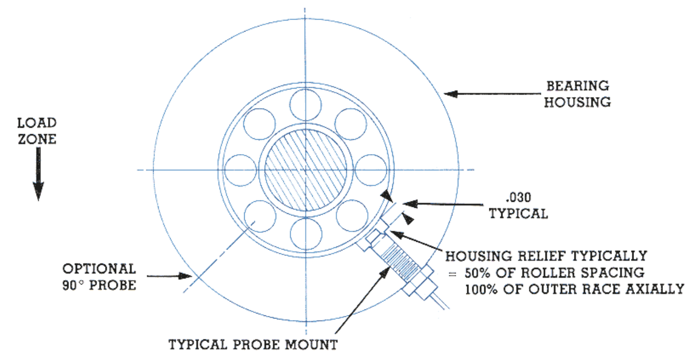
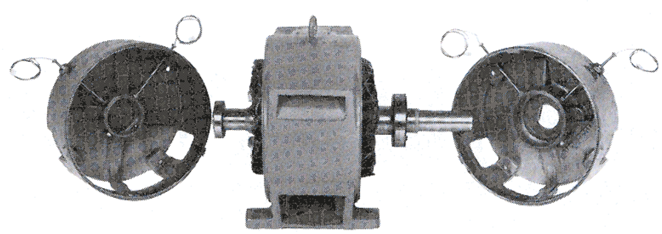


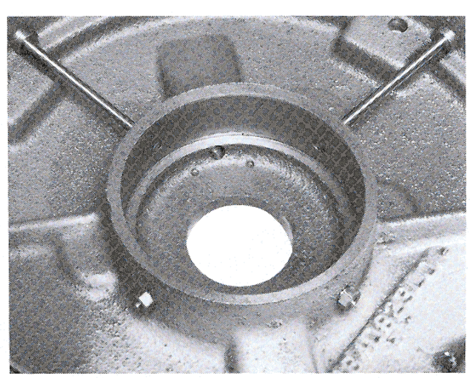
1 *Typical piezoelectric accelerometer response.*



2 *Typical probe mounting for rolling element bearing.*



3 *Probe installation on electric motor bearings.*



4 *Detail of probe installation on motor end.*

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to 60 times rotative speed, as shown in Figure 5.

Spike Repetition Rate

The spike repetition rate relates to whether the flaw is on the inner race, roller, or outer race. Sophisticated analysis of the spectra of flawed rolling element bearings, however, is often a situation of "beating a dead horse," because once a flaw occurs, it tends to generate more flaws.

Consequently, bearing analysis often involves asking two simple questions: Are there spikes above a normal operating level? How many spikes are there per unit time?

A clean, properly installed bearing with good lubrication will show no spikes. It will exhibit a normal level of rotative speed and rolling element frequency signals. Figure 6 shows the unfiltered and 1x filtered signals from a typical good bearing with a normal imbalance. No spikes are present.

Figure 7 shows spikes due to flaws. This bad bearing is carrying the same imbalance load as the bearing in Figure 6. Note the height and random nature of the spikes.

Considering the above information, the signal conditioning required for monitoring rolling element bearings is very straightforward. The approach is to connect the probe to one monitor (or portable instrument) which has two independent channels (or paths) of signal processing. One path incorporates a low-pass filter set to pass signals in the frequency region below five times shaft rpm. This path will then detect rotor-related motions (imbalance, misalignment, etc.) as well as roller passing frequencies which are indicative of bearing load. The second path has a high-pass filter which will pass those frequencies related directly to roller or race faults. Each path has its own adjustable alarm set point(s) and readout scale.

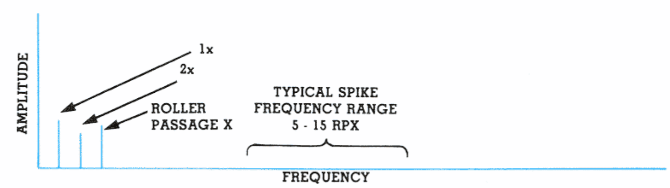
2-Path Signal Conditioning

This type of monitor signal conditioning has at least two advantages. The first is the availability of separate alarm set points for establishing maximum allowable displacement limits for each of the two malfunction categories. (It is often difficult to select one common limit which would be suitable for both classes of malfunctions.)

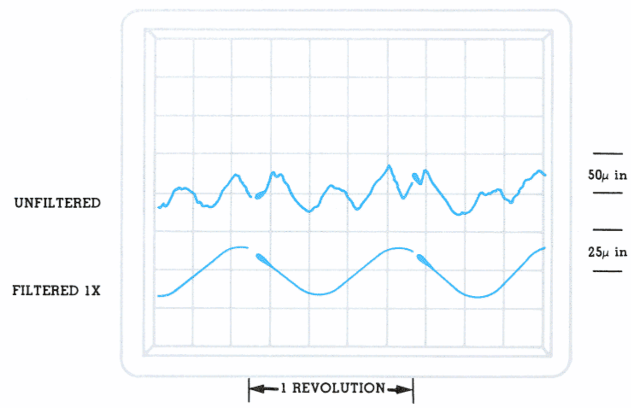
The second advantage is a direct result of the first. The separation of malfunction categories provides some fundamental machinery diagnostic capability at the monitor. Since this approach can indicate not only the presence of a machinery problem, but the potential source and magnitude of the problem as well, it allows the operator to take a more direct course of action in the event of an alarm condition.

For more information on the REBAM, call 800-227-5514, or contact your local Bently Nevada representative.

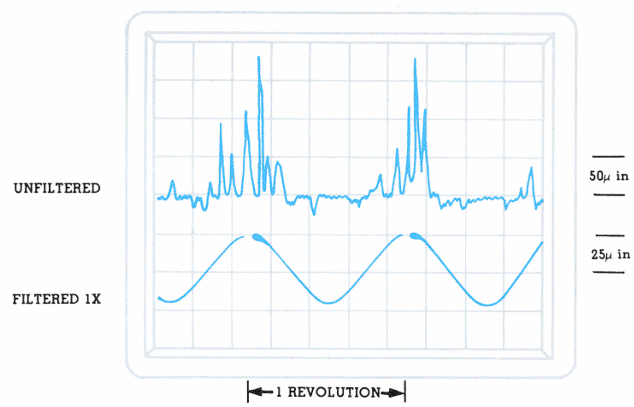
For literature on the REBAM, check L0472 on the return card.



5 *Typical spectrum content from rolling element bearing.*



6 *Known good bearing (note the smooth "roller passage" motion and lack of spikes).*



7 *Known bad bearing (note the spikes as roller traverse defects).*